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Title: Analysis and optimization of SONET/SDH network for Path Computation, Protection and Provisioning System.

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ABSTRACT

Synchronous Digital Hierarchy (SDH) and Synchronous Optical Network (SONET) are time-division multiplexing technologies that are used to provide the Bandwidth Services for the end user. High bandwidth applications and services requirements are provided by the SONET/SDH network. Because of this high bandwidth requirement fault tolerance and network recovery are important issues to optimize. Dynamic Service provisioning requires the use of online algorithms. These kinds of algorithms compute the efficient paths and proceed data flow in it. The allocation of the path depends on the service requests and bandwidth demand. SONET/SDH networks multiplexing techniques are used for this purpose to allocate the medium for desired Bandwidth. An engine is proposed for the use of application and use of dedicated path protection for the SONET/SDH network. Further proposal is to implement the dedicated path protection scheme and analyzed the performance matrices like blocking probability, Quality of services, etc. The performance is evaluated for different values for the relative weight of dedicated path for the complete and minimum information scenarios . Bandwidth is an important factor which is needed to optimize for efficient uses of SONET/SDH network. Moreover proposal is to study, analyze and implement Shared path protection. For High capacity backbone mesh network (Synchronous Optical Network/Synchronous Digital Hierarchy),a multipath provisioning system has been developed .The algorithm is suitable for the VCAT like issues. The work is carried out to support the SONET/SDH network using the dedicated path protection and Shared Path protection schemes. The enhancement has been made in the Dedicated and Shared Path protection schemes by means of the reliability of the services are enhanced. An engine has been created for dedicated path protection that provides the real time data services parameters specifications. Finally, the comparison has been made with the other algorithm in earlier work. The proposed algorithm provides more flexibility with small blocking probability without any cost.

Keywords- SONET/SDH network, Multipath protection schemes, Dedicated path protection and Shared Path protection Multi constraint paths, VCAT, ATM.

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1. Introduction

When data is transmitted over a communication medium, some things must be provided on the link, including framing of the data, error checking and the ability to manage the link. For optical communications, these functions have been standardized by the ANSI T1X1.5 committee as Synchronous Optical Networking (SONET) and by the ITU as Synchronous Digital Hierarchy (SDH). Here, attempts are made to describe how SONET/SDH works, down to the octet level .For a great many years, telephone calls were handled in the analog domain. Long distance calls were routed over twisted pair, coaxial cable, or analog microwave between major switching offices. In 1962, AT&T began installing DS-1 T-carrier services between long distance switching centers. Basically, these were channel banks2 which took 24 analog telephone circuits, converted them to digital and then transmitted them over copper to the other switching center, where they were converted back to analog. This worked very well – it reduced the number of copper circuits required between switching centers and improved the quality of the telephone calls (less noise and crosstalk).

As the volume of long distance grew, the number of T-carrier circuits required between switching centers increased. Additionally, DS-1C and DS-2 signals began to be used to increase the capacity of a circuit. In the late 1970's optical communications became feasible, allowing higher speed communications, which meant that one circuit could carry many more telephone calls. For example, one of the first commercial fiber circuits was installed in Chicago in 1977 and operated at 45 Mbps (DS-3 rate). The telephone companies looked at optical communications as simply a replacement for the older wire or microwave communications they had been using for years. But then they encountered a practical problem. Vendors of optical communications equipment had used their own framing techniques on the optical fiber. Once you selected a vendor, you were stuck with that vendor for all the equipment in that optical network. Thus was born the concept of standards in optical communications. It's extremely important to recognize that the first standards for optical communications were focused on handling voice circuits, and especially legacy plesiochronous channels like DS-1s and DS-3s. If we keep this fact in mind, many of the odd things about SONET and SDH will make more sense. At the time these standards were developed, the tremendous volumes of data traffic had not appeared and most people did not foresee it. Synchronous optical Network (SONET) offers cost-effective transport both in the access area and core of the network. For instance, telephone or data switches rely on SONET transport for interconnection. The optical layer provides the foundation of transport services for both metro and long-haul applications. It also directly supports data services. The optical layer is now evolving to provide the same level of sophistication that has been achieved with synchronous transmission, such as performance monitoring and network resilience .In SONET architecture the OC-N level signals and STS frames, as the frame structure knowledge is very much important as we said it was standard. So according to the SONET standards, which type of the frame structures are here to communicate among the nodes of the communication elements (in this case the telecommunication hubs). Analysis of virtual concatenation and VTs has been done for low data rate signals. Analysis of

Ethernet over SONET, Packet over SONET is also discussed and analyzed. From the analysis of SONET system it has been analyzed that the frame structure of the SONET. Now with the help of this knowledge of transmission and reception of the bits we can systematically derive the model of the SONET and SONET structure. As we studied that SONET is a standard. According to this standard design the SONET devices are also possible. Algorithm Development and design depends on many aspects like which type of application we wish to simulate and for which application we are going to design the aspects of communication link. As known that SONET mainly important Telecommunication so it may concern with high speed voice link but VTs allows us for lower data rate also.

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2. Literature Review

Although some publications are available in the area of SONET/SDH which talks about new value added services only a few of the publishes papers are relevant and reported in the list of references[1,2,3,4,5]. The literature published by the authors[6,7,8,9] have formed the base of the proposed dissertation entitled "Analysis and simulation of SONET/SDH network for optimization of path computation, protection and provisioning". However work carried out by Yuchin guol, Kuen chou loh ,Xchu.M Kodialam[10-14]have introduced novel features for next generation SONET/SDH network such as network segment ,legacy, DWDM system, ROADM(s),ATM,GPF,POS and soon have been very comprehensive and makes the backbone of the proposed research investigation.

2.1 Next Generation SONET/SDH Schemes

Powered with the knowledge of the current status of SONET/SDH, EoS and Packet over the SONET analysis of a domain of next generation SONET schemes are also possible. The SONET/SDH frame work is totally depending on the optical layer issues. VC is one of the key issue by which it can be possible to define the packets for the SONET frames. In the today's technology, SONET frames handling and the routing of the SONET is one of the key point. For that case, it is possible to also concentrate on some problems regarding the differential delays, routing schemes, and also network handling protocols.

The researchers are going on for different type of the technology for the designing of new generation SONET frame work in all the areas: hardware (Multiplexers, Demultiplexers, ROADMs DCS etc..), Software (Routing algorithm) and in system problem issues like Differential delay minimization. Collectively all the upgraded issues and technologies we can define new sections for SONET frame work. The management and control of the SONET is also one of the key issues for next generation SONET.

The Demand for new communication services and high user-end bandwidth is a driving force for high capacity networks and thus high data transmission rates. Many research and development efforts have been focused on the next generation 10 Gb/s serial communications systems, e.g., 10 Gb-Ethernet and SONET OC-192, and initial products have been demonstrated

with satisfactory performance. However, with the further increase of data transmission rates, packaging is becoming a major barrier. Take SONET OC-768 as an example, 40 Gb/s digital signal transmission (50 Gb/s when using some suggested forward error correction schemes) will require a package that works fairly well up to 60 GHz—the third order harmonic of the equivalent primary frequency. Traditionally package designs above 20 GHz have been focused on narrowband applications, and packaging design options for wideband performance become very limited at higher frequency range, especially for off-chip interconnections. The parasitic inductance of a wire bond significantly degrades the signal integrity at this high frequency [15]. Flip-chip appears to be a better solution, but it also shows limitations, such as parasitic capacitance of the bump pad and the design complexity because of the use of under fills and coupling effects [16]. Differential delay between the members of VCG can be minimized using suitable path selection. The problem of finding ***a*** new *STS-**n*** channel that can be added to the existing VCG as a hounded-delay path selection problem in [17]. Performance of K-shortest-path algorithm is compared with the modified link weight K-shortest-path algorithm. Our simulations indicate that the latter algorithm performs significantly better than the original K-shortest-path algorithm according to .Moreover the complete analysis of the current structures of SONET/SDH frame works and layout. With the power of current technology knowledge, now it is possible to define the next generation implementation which has been discussed and optimized. This knowledge of the implementation defines the new algorithms and new devices like Reconfigurable Add Drop Mux, DCSs Routing algorithm at highest optimized level.

3. Description of the Broad Area/Topic

Bandwidth Requirement is one of the critical issues in the current environment of high speed communications. It also effects for the network operators and service providers in terms of communication business. That is the reason which forces the Engineers to generated different types of services like PDH, SONET/SDH, WDM, DWDM, ATM, DSL etc. There is also need of providing different QoS for different users. This directly affects the revenue of Service providers. The provisioning is handled manually by the service providers. The Service providers manually log into the network. Arrange the activities and parameters of the network like required QoS, available network resources, and the ability to accommodate future requests before starting the work of provisioning a requested service. For this purpose the service provides has to log in to the Management systems and issue the command for the same.

3.1 Dedicated Protection

There is one of the main point which is needed to take into consideration is the availability of the Bandwidth services. This is an important area of research to find the maximum availability of Bandwidth in a dense network. It implies manual path computation and maintenance of huge inventory details. Then, the configuration on the network elements involved has to be done. These processes, being manual, are tedious and more error-prone.

One of the solutions for this problem is to have an automatic provisioning system. For such kind of system it is important to have inventory details from the database. For this Element Management Systems, or Network Elements directly should be accessible and it should be able to issue the configuration commands so that the requested capacity can handled easily. Another important task is to collect the information for the working path, links, nodes, node-disjoint path. This information can provide availability of working path, used path, free capacity etc.

In SONET/SDH network, there is need to establish working and protection path for reliable operation. Dedicated and Shared Path protections are the two techniques used for efficient use of Bandwidth in Network. In dedicated-path protection, a protection path to protecting a particular working path exclusively is provided, whereas in shared-path protection, a protection path can be shared by many working paths [17]. In both cases, the constraint is that a working and its protection path have to be diversely routed so that at least one path can survive a single failure in the network . In Synchronous Digital Hierarchy (SDH), protection against the failure is more complex. This is because it is used by many service providers to have main backbone traffic and also provide bandwidth services . E1, E4, DS1, DS3 etc. are the signals which are used by the SDH network which is mentioned in G.703. The protection provided by the SDH is Multiplex Section Protection (MSP), Multiplex Section–Shared Protection Ring (MS-SPRing) [18], and Subnetwork Connection Protection (SNCP).

3.2 Design for dedicated protection

Dedicated path protection is analyzed, implemented and enhanced for a dense network. A working engine has been created using the MATLAB tool and analysis has been done for multiple requests. The engine can hold the network for the static analysis and can provide better and enhanced way for the dedicated protection mechanism. The Engine is also able to handle Multiplexing Hierarchy. For dedicated-path protection, a working path and a link and/or node-disjoint protection path that protect only failures in that working path have to be found. In [19] a simple algorithm has been proposed in which shortest path algorithm has been used for finding the shortest path algorithm store this path and then removes this path temporarily and also removes its associated parameters from network then again run the shortest path for the dedicated path protection. This is Two step Heuristic approach employed in this paper. This approach has the limitation that it may not find a path pair even if it exists or it may not be optimal. A polynomial time optimal algorithm to find a link-disjoint path pair is proposed in . Computing link-disjoint paths for QoS routing under multiple constraints is addressed in [19].

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Consider a network which is created of following:

1. Physical links (Solid Lines)
2. Logical Links (Trails)
3. Nodes

Problem statement is to provide service to the service request from a to m. *abclm* is the shortest path computed from a to m and next generated shortest path is *ahjkem*(see fig.).Overlaps for such cases are dk since the trails *cl and ke* have a traversing through them. So these two paths cannot make the disjoint path pair. The link dk will be interlaced by the computed path pair and we can obtain the abcdem and ahjklm finally after removing it. This condition is associated with [20] and the following points are important to discuss:

If two disjoints paths are Pd1 and Pd2 and P1 is the shortest path belonging to them. Then

1. P1 itself is Pd1 or Pd2 , i.e.P1=Pd1, or P1=Pd2 ;
2. P1 overlaps with both paths Pd1 and Pd2, i.e.,P1∩Pd1= φ , P1≠Pd1 and P1 ∩ Pd2= φ, P1≠Pd1.

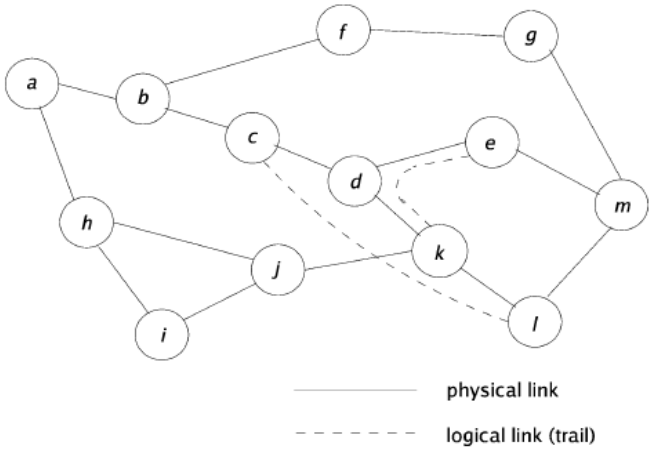

Fig. 1 A sample Network

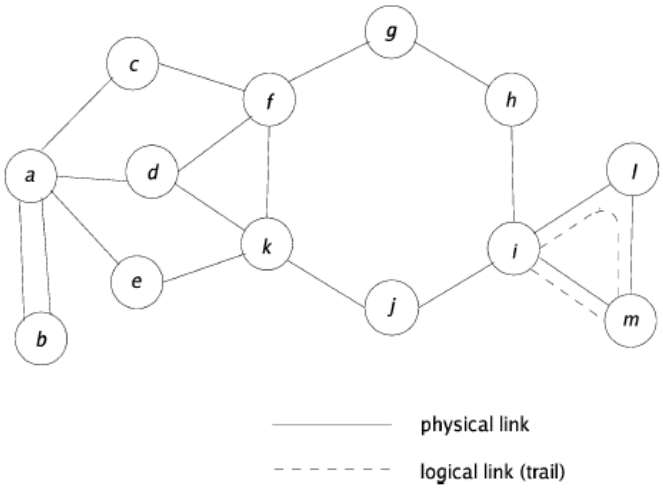

Fig. 2: A sample Network with Standard SDH protection Scheme

Algorithm for Dedicated Protection is now discussed here. Path computation algorithms for SDH networks under dedicated protection have to take into account the constraints imposed by SDH multiplexing hierarchy and the standard protection mechanisms provided by it [22]. Two protection paths will exist for those segments of the working path that have standard protection

mechanisms, which results in unnecessary wastage of bandwidth. For traffic from *b* to *m* in the network shown in Fig.2, let us assume the working path is *badfghim*. This path contains *ba*, which is part of an MSP, *fghi*, which is part of an MS-SPRing, and the trail *im*, which is part of an SNCP . In this case, the protection path can use the inherent protection paths corresponding to those segments and use a disjoint path for the other segments, which in this case is *adf* instead of finding a disjoint protection path from *b* to *m*.

There are some algorithms which are shown in [25]. These algorithms are implemented in this paper and an enhanced engine is developed for the dedicated path protection. Algorithm 1 is used for dedicated path protection. The algorithm is used for the computation of the two paths for the handling of the service request under dedicated protection scheme. The inputs for this algorithm are source, destination, and standard rate. The outputs are dis joint path pair as output.

The algorithm has iterations to provide the best result. The algorithm runs *i*th iterations, for *i*th iterations it has *i*th shortest path. The shortest path is founded by the Yen's K shortest path algorithm [28].

An improved version of Yen's algorithm is provided in the [29] is used for the shortest path in protection of path and provisioning. The algorithm provides the disjoint path in each iteration. If the shortest path does not exist than break the loop. If capacity is not available in the first ith shortest path then it switch to the next iteration. The iteration goes on till the dedicated shortest path not found. A protected path is also calculated except primary physical link. This protection path is used as backup path if any failure in primary is encountered.

While computing a disjoint path pair, the direction of the seed path is reversed and weights are made negative . This can be done only if the seed path is the shortest path; else it may result in negative cycles. This is achieved by having a flag, which is true for the first shortest path and false for the rest, indicating when the weights have to be inverted. For the paths to be link-disjoint, all the trails except those in the *i*th shortest path that traverse the links traversed by the *i*th shortest path, and all the links traversed by the *i*th shortest path but not in the th shortest path are removed temporarily. Then, the th shortest path is split into segments that are either part of or not part of one of the standard SDH protection mechanisms. This is done by iteratively going through the trails and checking whether the trail itself or the edges it passes through have standard protection.

If it has no protection, then it is added into a list. If it has protection and the protection instance is the same as that of previous edge or trail, then it is added into a second list. If there is a shift from no protection to protection or protection to no protection, the first or second list, respectively, is the segment that is used in the subsequent steps. Then, the lists are reset as empty, and the procedure repeated until the end of the path. For the segments that are part of some standard SDH protection scheme, its inherent protection path is added to . For the other segments, the Edge-disjoint Path Pair (EPP) , which returns an edge-disjoint path pair is used with that segment as the working path. Finding inherent protection paths for segments that are part of MSP or SNCP is straightforward since the protection path is fixed in those cases.

3.3 Shared Protection Path

The emergence of SONET technology has provided a promising solution to the ever increasing demand for telecommunications bandwidth over recent years. However, as a consequence of the high bandwidth demand, fault tolerance and network recovery have become important issues. Each channel transmitting at rates over 100 megabit per second, even one failure of fibre can result in severe data and revenue losses, with multiplexing of wavelength. Service providers have been forced to seriously consider resilience mechanisms and schemes that could improve the performance of their networks and keep their customers satisfied.

The Service Level Agreement is a contract between the service provider or network operator and the customer that stipulates certain Quality of Service (QoS) guarantees[30]. The operator may bear financial penalties if the QoS doesn't meet the requirements. , One of the main concerns of the operator is to provide satisfiable connections to avoid penalty, along with minimizing resources and cost. There are several approaches that can be considered to ensure resilience in SONET[31,32]. These are based on two basic survivability paradigms:

1.Path/Link Restoration

2. Path/Link Protection

Recovery involves the rerouting of normal traffic by traversing the working path (WP) over a new path called the backup or protection path (PP). In general, restoration is a dynamic scheme whereby spare resources are used to find recovery paths at the time the failure occurs.

Restoration schemes therefore have the advantage of being more efficient than protection schemes since they utilize spare capacity only when required. Whereas, the schemes of dedicated protection reserve resources in advance to cater for possible scenarios of failure. Dedicated protection schemes, shared-backup protection were introduced to improve resource utilization and allowing the sharing of backup resources between connections when the corresponding working resources are mutually diverse. These two methods could be applied to either the links that make up end-to-end connections or entire paths from sources to their respective destinations.

A major aspect of future optical networks will be the ability to provide fast provisioning along with recovery of efficient network. So, shared-path protection may be used due to its recovery speed, efficient resources and providing guarantees on its restoration ability. Therefore, for achieving this, there is a need for a union control plan and algorithms that should bear the responsibility for the management of Routing and Wavelength Assignment (RWA) protocols and the setup and tear down of connections. Different QoS requirements are also important, since different customers need different levels of fault tolerance and differ in their willingness to pay for a guaranteed service. Service providers will be benefited by providing such services with different levels of reliability by improvement of efficient resource utilization and allowance of service scalability.

3.4 Design for Shared Path Protection

The backup path may either be path based (i.e. from the source to destination node) or link based (i.e. from a node preceding the failure to a node succeeding the failure) So, paradigms of survivability can broadly be classified using four criteria: Execution, Computation, Rerouting and Resources.

a. *Execution*

Survivability scheme may be employed by a network that is executed and controlled either centrally or in a distributed manner. A central controller involved by the centralized scheme, where a source node generates requests which are to be received. The routing and wavelength assignment have been done by the controller while updating and maintaining the network status. Frequent communication required between the nodes and the central controller, to update them, which results in overhead and if the network size increases it will become problematic. No central controller is present in the distributed schemes. The operation of network is like a two level network with a network of data for physical transmission.

b. *Computation*

Backup or recovery paths may be computed prior or subsequent to the failure occurrence. Protection schemes use the pre-computed approach to calculate backup paths before the occurrence of failure. Alternatively calculation of the backup path by the restoration schemes in real time, after the occurrence of failure. Protection schemes have the advantage of offering fast recovery due to the pre-computation of backup paths. Restoration schemes have the advantage of efficient resource utilization since backup paths are computed only once a failure has occurred. For failure identification, time determining the recovery path and current status. These restoration schemes are slow and unattractive. Centralized schemes which involve pre-computed routes are conducive for practical implementation.

c. *Rerouting*

The backup paths may either be path based or link based. Link based approaches employ local detouring of disrupted traffic around the failed link. Path based rerouting methods provide end to end detouring by computing backup paths from the source node to the destination node.

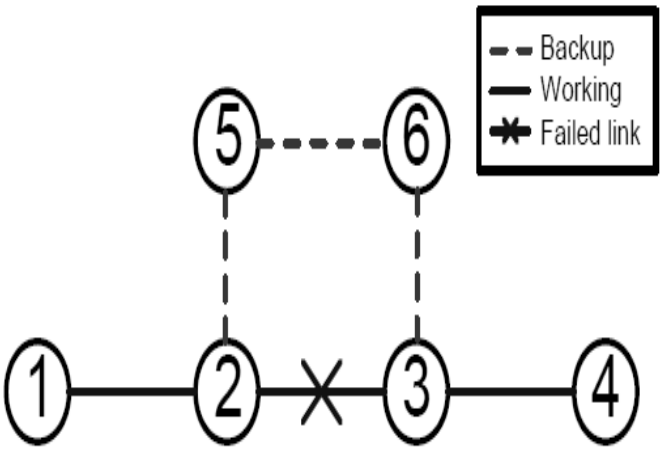

Fig. 20: Link based

Sub-path protection involves dividing the WP into a number of segments and protecting eachsegment separately. Compared with path protection, sub-path protection can achieve high scalability and fast recovery for a modest sacrifice and resource efficiency.

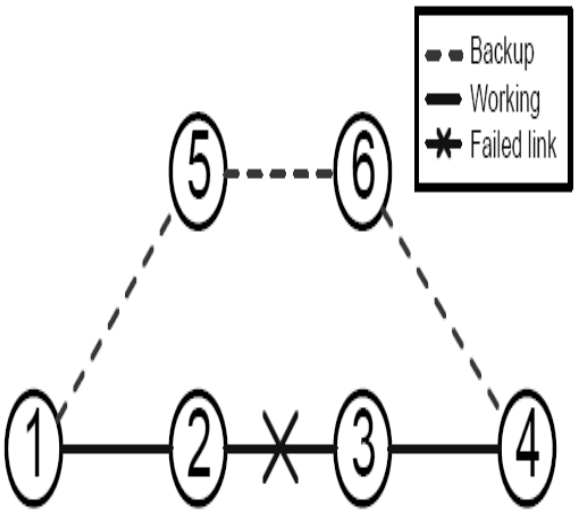

Fig. 21: Path based

d. *Resources*

Survivability schemes also differ with respect to how backup capacity or resources arc utilized. Dedicated techniques specify that each primary path should have its own dedicated backup path. In protection schemes, dedicated protection is classified into 1+1 and 1:1 schemes. In 1+1 protection, data is transferred to both the primary and secondary paths simultaneously,

whereas in the 1:1 case, data is sent over the primary path only and the secondary path may be used for other low priory traffic. When the failure does occur, traffic is switched over to the backup path. 1:1 protection makes more efficient use of capacity but it is slower too. Dedicated schemes therefore use twice the bandwidth required for transmitting data to protect connections against single link failures. In the shared case, primary paths may share the same backup resources as long as the primary paths are disjoint of node and link. Backup multiplexing is done by shared approaches. To improve utilization of link, resources are shared among backup paths and these are categorized as shared-backup path protection schemes, in M:N protection. Segment shared protection may also be the form of shared protection , where protection segments may be shared between different working path

4. Problem Identification

The main problem in SONET/Bandwidth Requirement is one of the critical issues in the current environment of high speed communications. This also effects for the network operators and service providers in terms of communication business. That is the reason which forces the Engineers to generated different types of services like PDH, SONET/SDH, WDM, DWDM, ATM, DSL etc. There is also need of providing different QoS for different users. This directly affects the revenue of Service providers

5. Objectives

The main objective of this research work is to design and optimization of path computation , protection and provisioning of shared and dedicated process.

1. Study and Analysis of SONET/SDH for shared and dedicated path protection
2. Optimization of shared path protection for path computation, protection and provisioning
3. Optimization of dedicated path protection for path computation, protection and provisioning

In this research a novel approach has been described .Following are the motive of the implementation of dedicated path protection algorithm: To improve bandwidth consumption as per request, allows multiple requests to be generated to decrease wastage as in transport networks which have fixed leased lines and hence wastage of available resources.

6. Methodology

The work is divided in two parts (1) Shared path protection (2) Dedicated path protection

The Methodology depends on the concept that how much optimized research we need to do. The sharpness of optimization depends on the intelligent methodology. The project is divided into two parts: Shared path protection and dedicated path protection. To improve bandwidth consumption as per requests. Allows multiple requests to be generated to decrease wastage as in transport networks that have fixed leased lines and hence wastage of available resources.. Algorithm Development and design depends on many aspects like which type of application we wish to simulate and for which application we are going to design the aspects of communication link. As we know that SONET mainly important Telecommunication so it may concern with high speed voice link but VTs allows us for lower data rate also.

The methodology can be explained in following steps:

1. Detailed analysis of SONET/SDH architecture
2. Analysis of path protection mechanism available in SONET/SDH network
3. Study and survey of dedicated path computation, protection mechanism
4. Study and survey of shared path computation, protection mechanism
5. Optimization of dedicated and shared methods for path protection, provisioning mechanism.
6. Analysis of results

7. Proposed/Expected Outcome Of The Research

The outcome of this research entitled "Anaysis and Simulation of SONET/SDH network for optimization of Path Computation, Protection and Provisioning System" shall be optimized bandwidth for service provider. New algorithms for shared path protection and dedicated path protection has been proposed and also the criteria for the evolution and optimization of the bandwidth oriented structure. The proposed algorithms will provide better throughput, blocking probability and optimization of bandwidth than other existing algorithms. If the SONET/SDH network is implemented using the above inferences as the criteria for its operation, then the functional capacity of the network increases by 50% (as compared with the *non-bandwidth-optimized* networks; in the testing environment). This implies that, it will give 50% more acceptance rate for all the incoming/outgoing voice and data channels. This percentage might be affected by the hardware quality, routers in remote area locations, demographics, topography, power management units, and even by other environmental effects.

It may be possible to get at least three full research papers and one intellectual property right (IPRs) from this dissertation.

8. **Proposed Time Frame**

The proposed research work will be completed in the following phases:

Phase I – Course work & Literature Survey of the broad area of research.

Phase II – Literature survey on the latest trends available in SONET/SDH Network ,VCAT,LCAS,GPF Techiques available

Study of the past and present status of shared and dedicated path mechnism.

Phase III – Study and Analysis of SONET/SDH for shared and dedicated path protection mechanism

Phase IV – Design and Optimization of shared path computation ,protection and provisioning mechanism

Phase V – Design and Optimization of dedicated path computation ,protection and provisioning mechanism

Phase VI – Analysis of Results obtained.

Phase VII – Writing of Thesis.

It is envisaged that the research work will progress as per the detailed plan.

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